

MINING DARK INFORMATION RESOURCES TO DEVELOP NEW INFORMATICS CAPABILITIES TO SUPPORT SCIENCE

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Project Team:

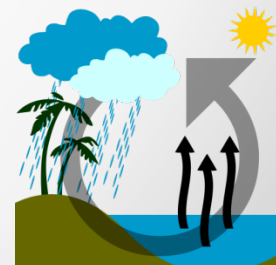
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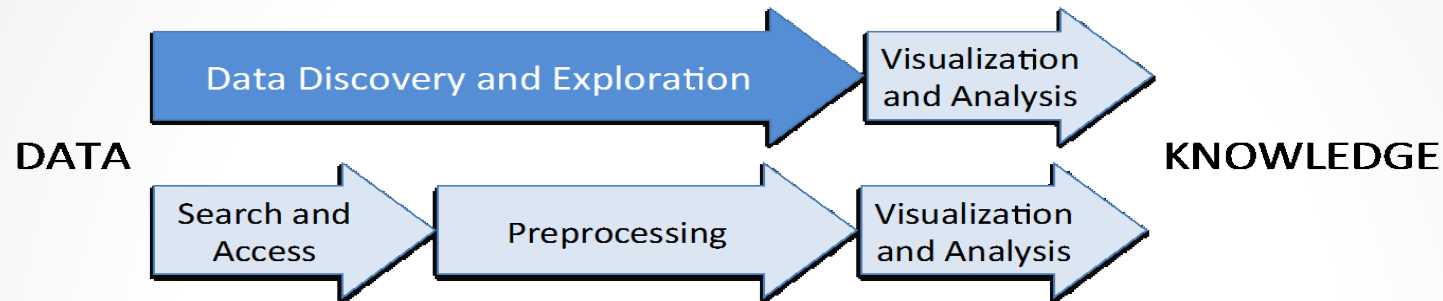
Outline

1. Project Overview
2. Data Curation Service
3. Rules Engine
4. Image Retrieval Service
5. Summary

Part 1: Project Overview

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Motivation



- Data preparation steps are **cumbersome** and **time consuming**
 - Covers discovery, access and preprocessing
- Limitations of current Data/Information Systems
 - **Boolean search** on data based on instrument or geophysical or other **keywords**
 - Underlying **assumption** that users have sufficient knowledge of the **domain vocabulary**
 - **Lack support** for those **unfamiliar** with the domain vocabulary or the **breadth of relevant data** available

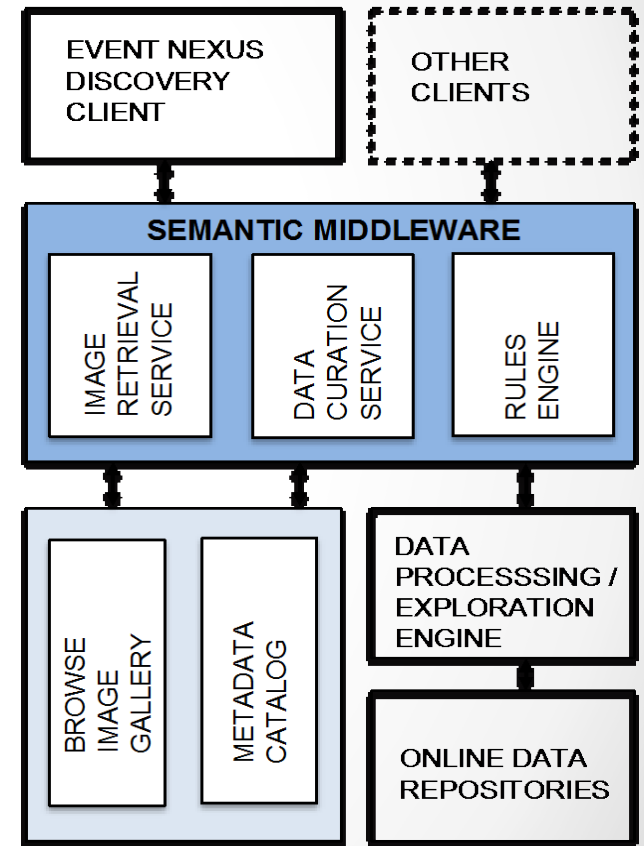
Earth Science Metadata: Dark Resources

- *Dark resources* - information resources that organizations collect, process, and store for regular business or operational activities but fail to utilize for **other** purposes
 - Challenge is to recognize, identify and effectively utilize these dark data stores
- Metadata catalogs contain dark resources consisting of structured information, free form descriptions of data and browse images.
 - NASA's Common Metadata Repository (ECHO) holds >6000 data collections, 270 million records for individual files and 67 million browse images.

Premise: Metadata catalogs can be utilized *beyond their original design intent* to provide *new data discovery and exploration pathways* to support science and education communities.

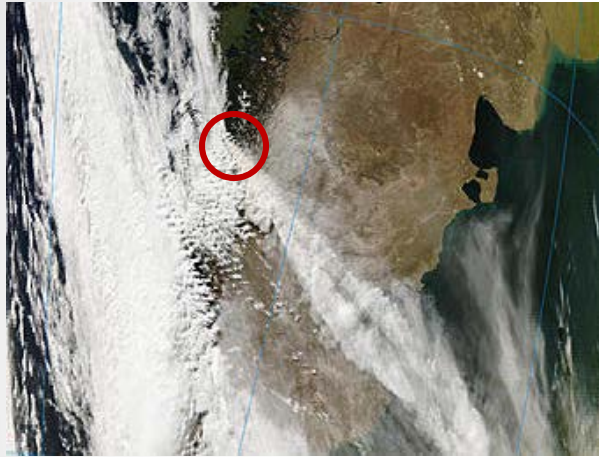
Project Goals

- Design a Semantic Middleware Layer (SML) to exploit these metadata resources
 - provide novel **data discovery and exploration** capabilities that significantly reduce data preparation time.
 - utilize a varied set of semantic web, information retrieval and image mining technologies.
- Design SML as a Service Oriented Architecture (SOA) to allow individual components to be used by existing systems

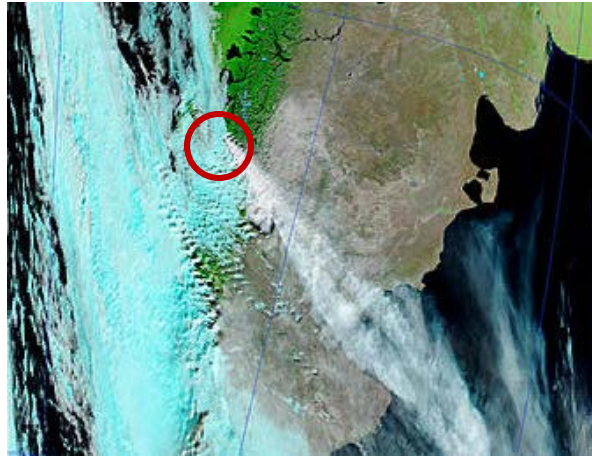


Use Case:

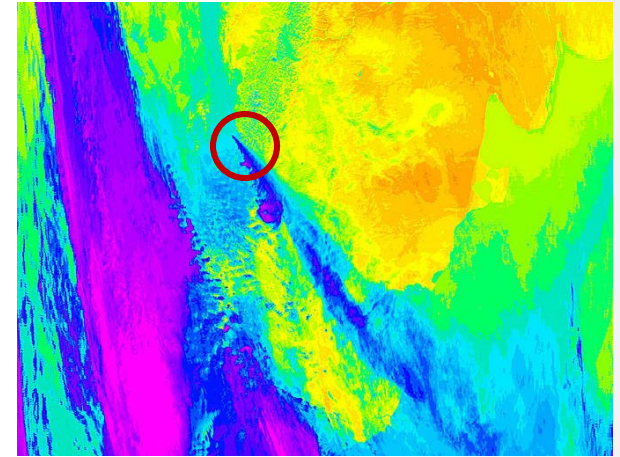
Find Interesting Events from Browse Images



Band 1-4-3 (true color)



Band 7-2-1



LST

Example: MODIS-Aqua 2008-05-03 18:45 UTC

Chaitén Volcano Eruption

Eruption Time period: May 2 – Nov 2008

Location: Andes region, Chile (-42.832778, -72.645833)



Image Retrieval Service can be used to find volcanic ash events in browse imagery

Suggest Relevant Data

Total SO₂ mass:

e.g. **Chaitén** is 10 (kt) =(kilotons) , (1kt= 1000 metric tons)

ftp://measures.gsfc.nasa.gov/data/s4pa/SO2/MSVOLSO2L4.1/MSVOLSO2L4_v01-00-2014m1002.txt

Daily SO₂:

OMI/Aura Sulphur Dioxide (SO₂) Total Column Daily L2 Global 0.125 deg

http://disc.sci.gsfc.nasa.gov/datacollection/OMSO2G_V003.html

Calibrated Radiances:

MODIS/Aqua Calibrated Radiances 5-Min L1B Swath 1km

<http://dx.doi.org/10.5067/modis/myd021km.006>

Aerosol Optical Thickness:

MODIS/Aqua Aerosol 5-Min L2 Swath 10km

<http://modis-atmos.gsfc.nasa.gov/MOD08>

SeaWiFS Deep Blue Aerosol Optical Depth Data 13.5km

<http://disc.gsfc.nasa.gov/datacollection>

**Data Curation Service
recommends relevant
datasets to support event
analysis**

IR Brightness Temperature:

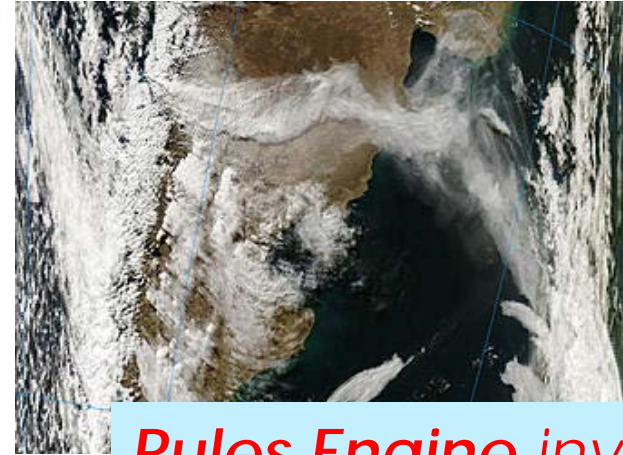
NCEP/CPC 4-km Global (60 deg N - 60 deg S) Merged IR Brightness Temperature Dataset

Generate Giovanni SO2 Plots

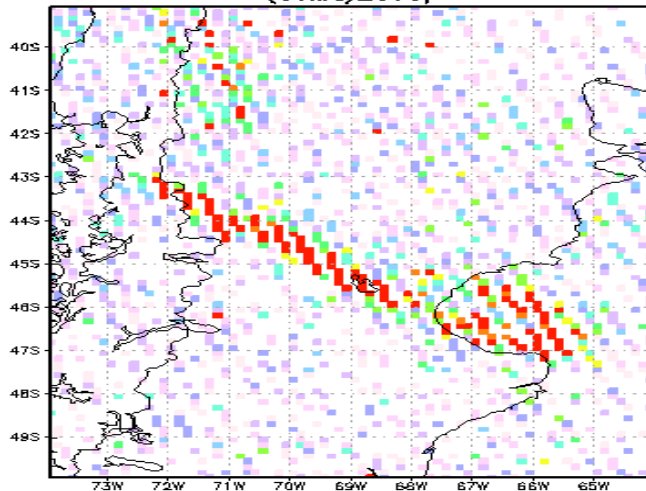
MODIS-Aqua 2008-05-03 18:45 UTC



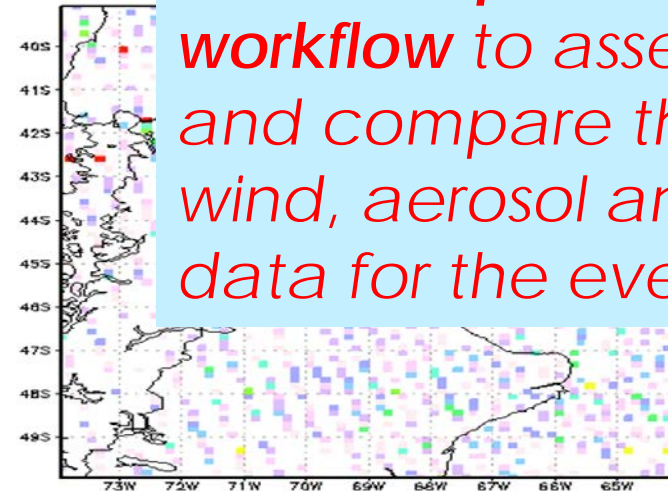
MODIS-Aqua 2008-05-05 18:30 UTC



2G.003 SO2 Column Amount (Planetary Boundary La
(03May2008))



2G.003 SO2



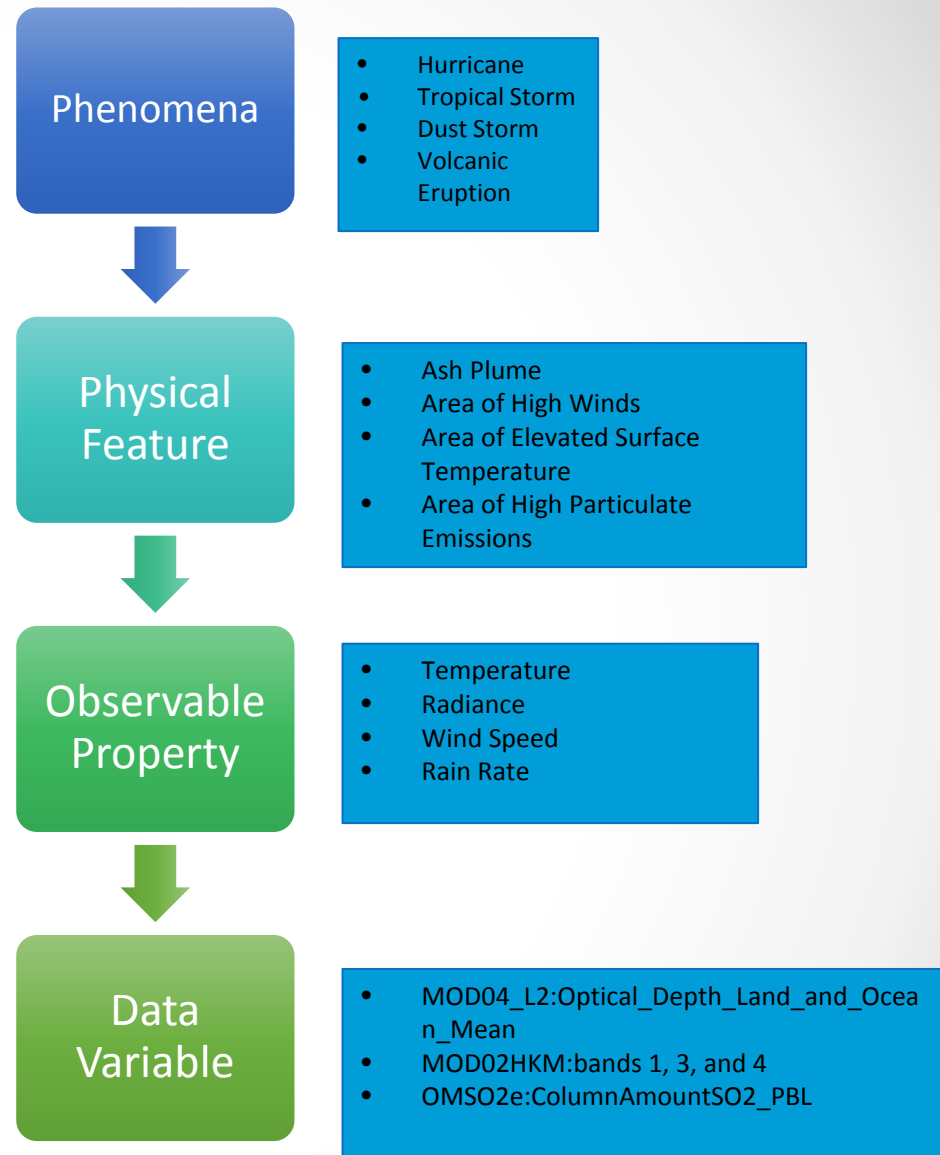
Rules Engine invokes a Giovanni processing workflow to assemble and compare the wind, aerosol and SO2 data for the event



http://gdata2.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=omil2g

Conceptual Model

- **Phenomena**
 - Event type
- **Physical Feature**
 - Manifestation / Driver of phenomena
 - Has space/time extent
 - Can precede or linger after what is generally thought of as the phenomena event
- **Observable Property**
 - Characteristic/property of physical feature
- **Data Variable**
 - Measurement/estimation of observable feature



Part 2: Data Curation

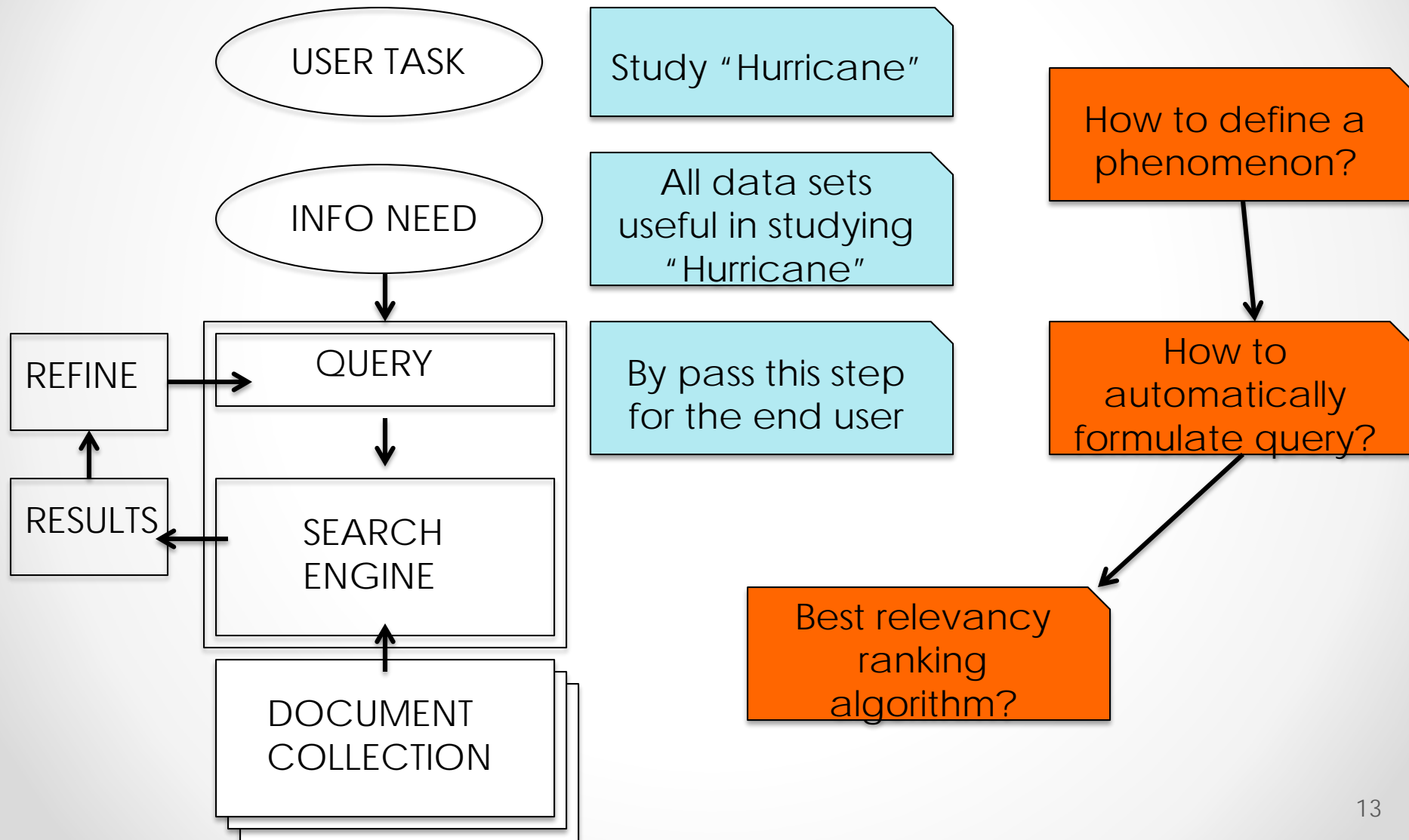
Algorithm for Phenomena

...

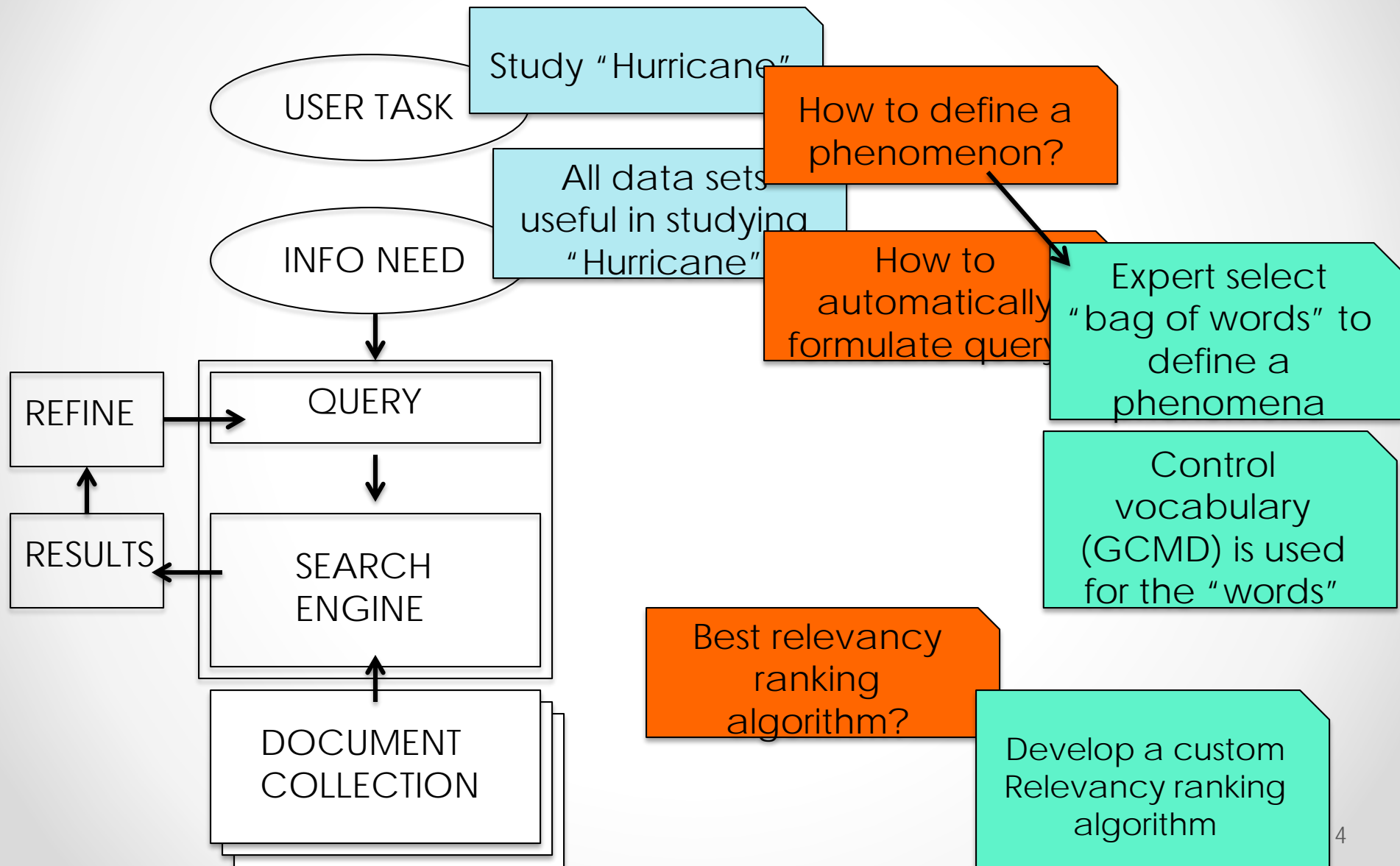
Objectives

- Design a data curation (relevancy ranking) algorithm for a set of **phenomena**
- Provide the data curation algorithm as a stand alone service
- Envisioned Use:
 - Given a phenomenon type (Ex: Hurricane), DCS returns a list of relevant data sets (variables)
 - $\langle \text{list of data sets (variables)} \rangle = \text{DCS(Phenomenon Type)}$
 - For a specific phenomenon instance (event: Hurricane Katrina), these curated datasets can be filtered based on space/time to get actual granules

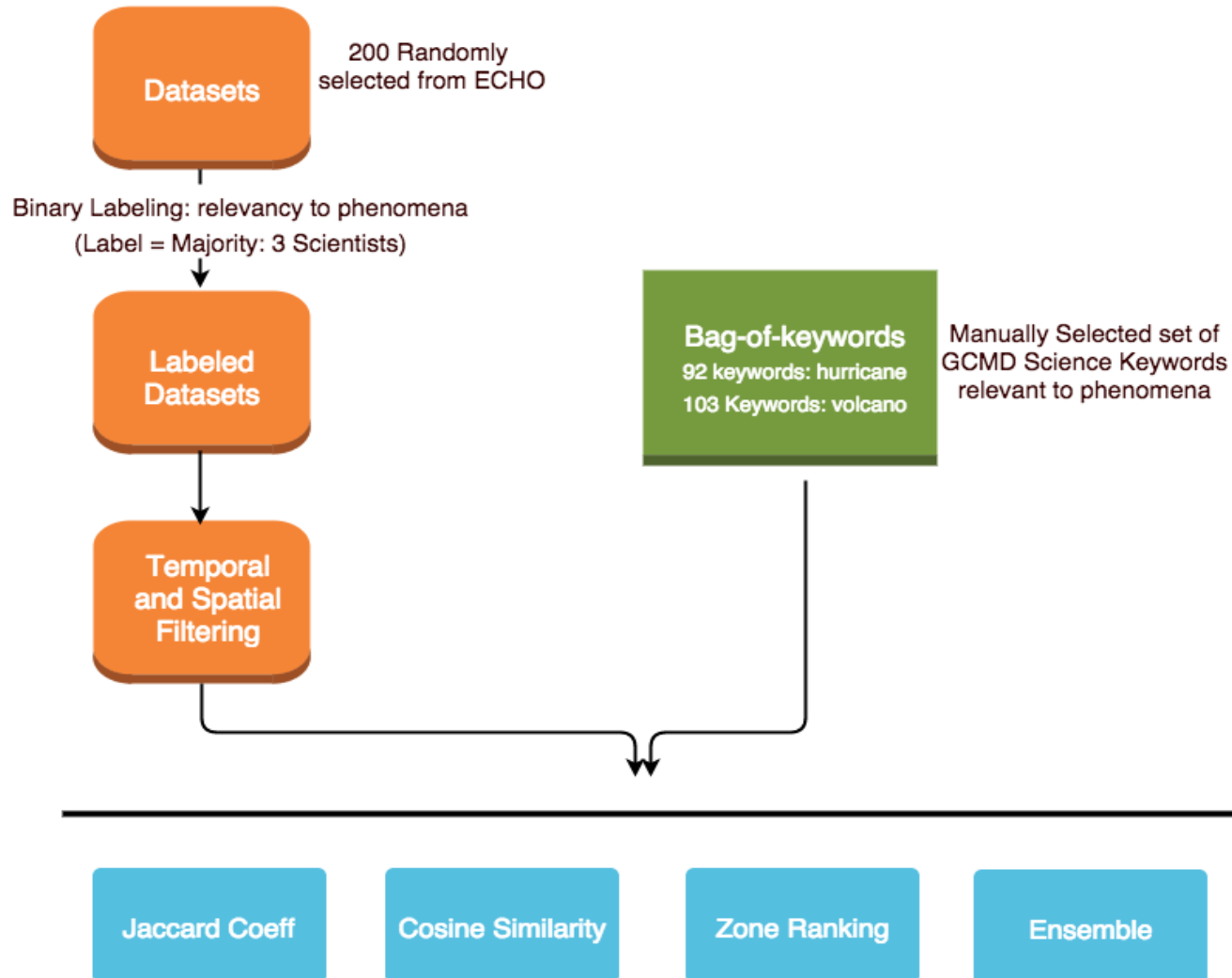
Data Curation is a Specialized Search Problem



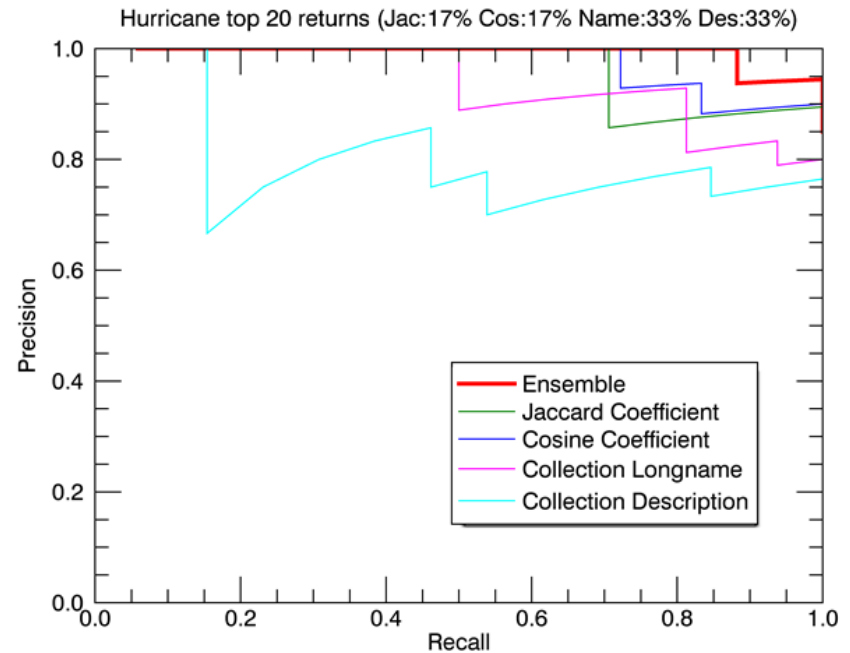
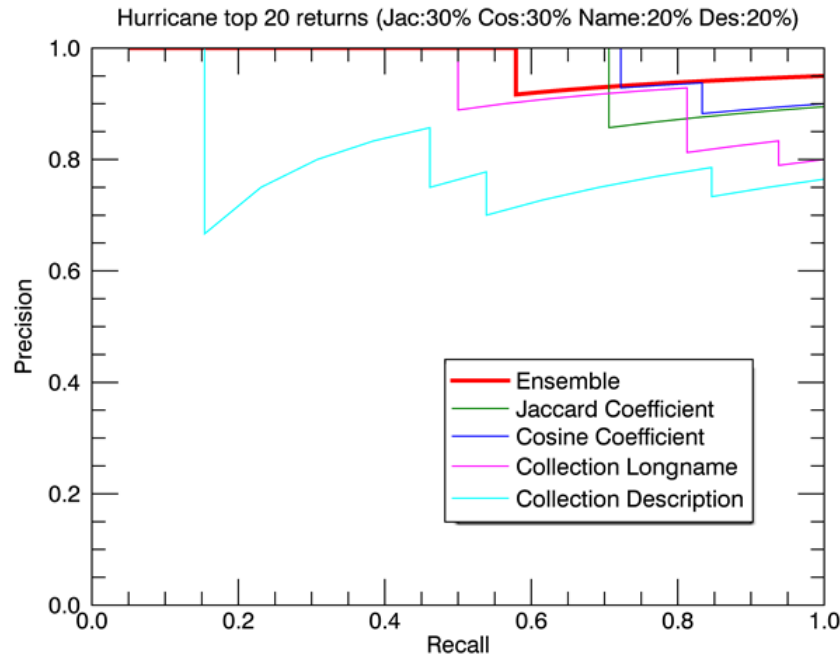
Our Approach



Experiment Setup



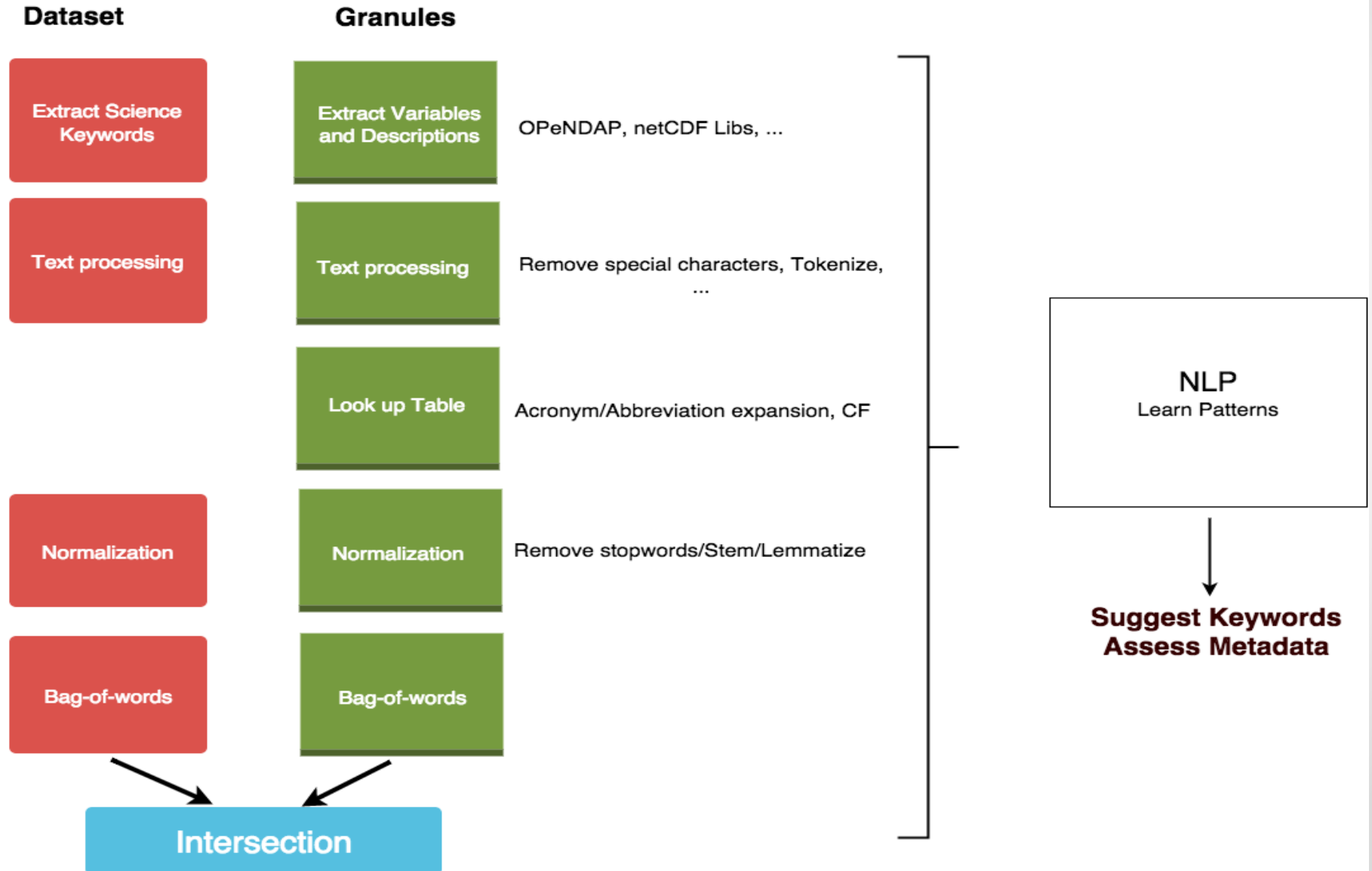
Top 20 returns (Hurricane)



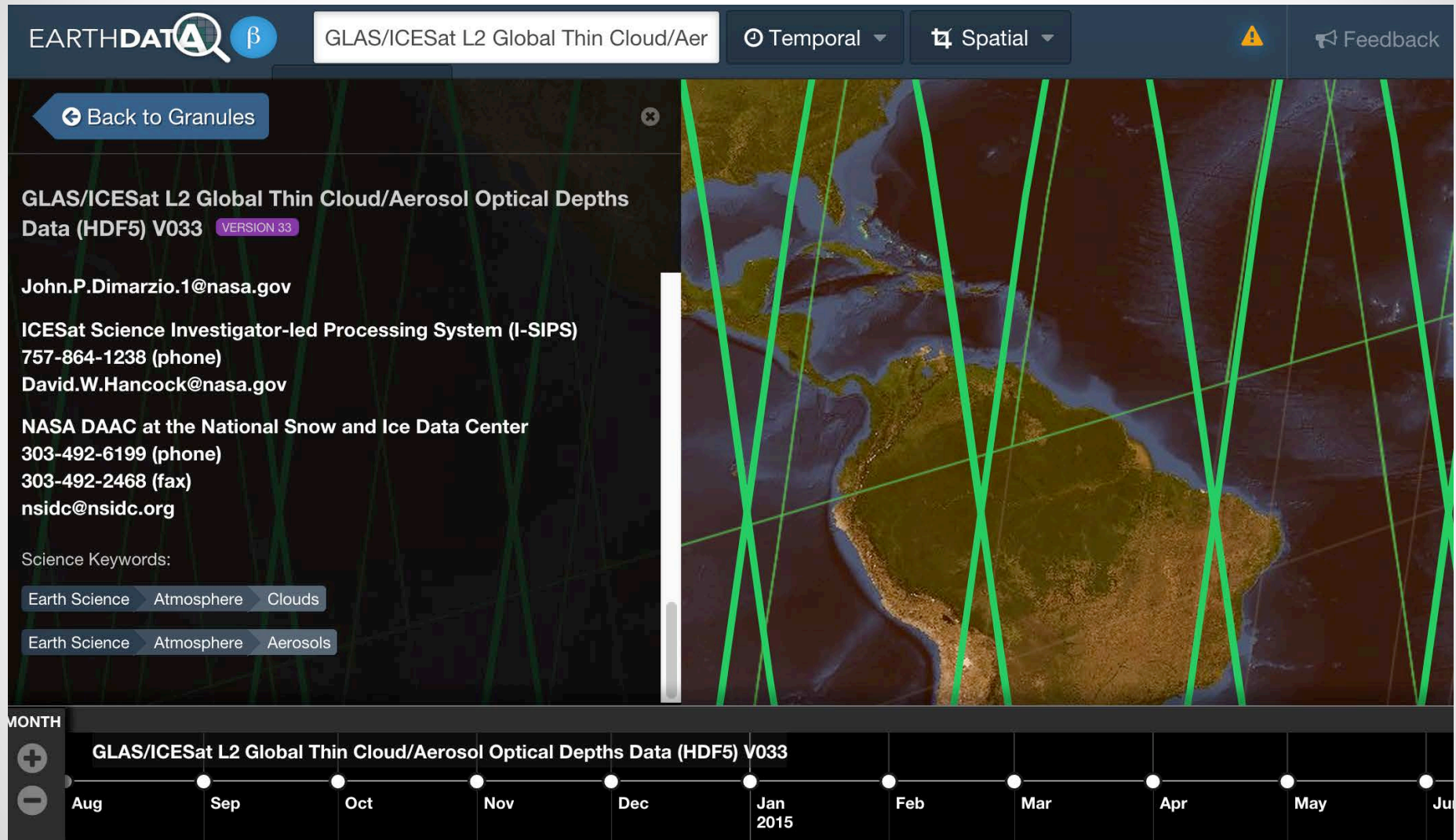
Next: Find relevant data fields

- Need actual data variables
 - Example: Giovanni uses these fields for visualization
- What we know
 - Data set (Collection) level science keywords (GCMD) – Experts
 - Granule data fields and metadata – Auto extract*
- How do we map?
 - Start with GCMD to CF Standard name
 - Most don't follow CF Standard names

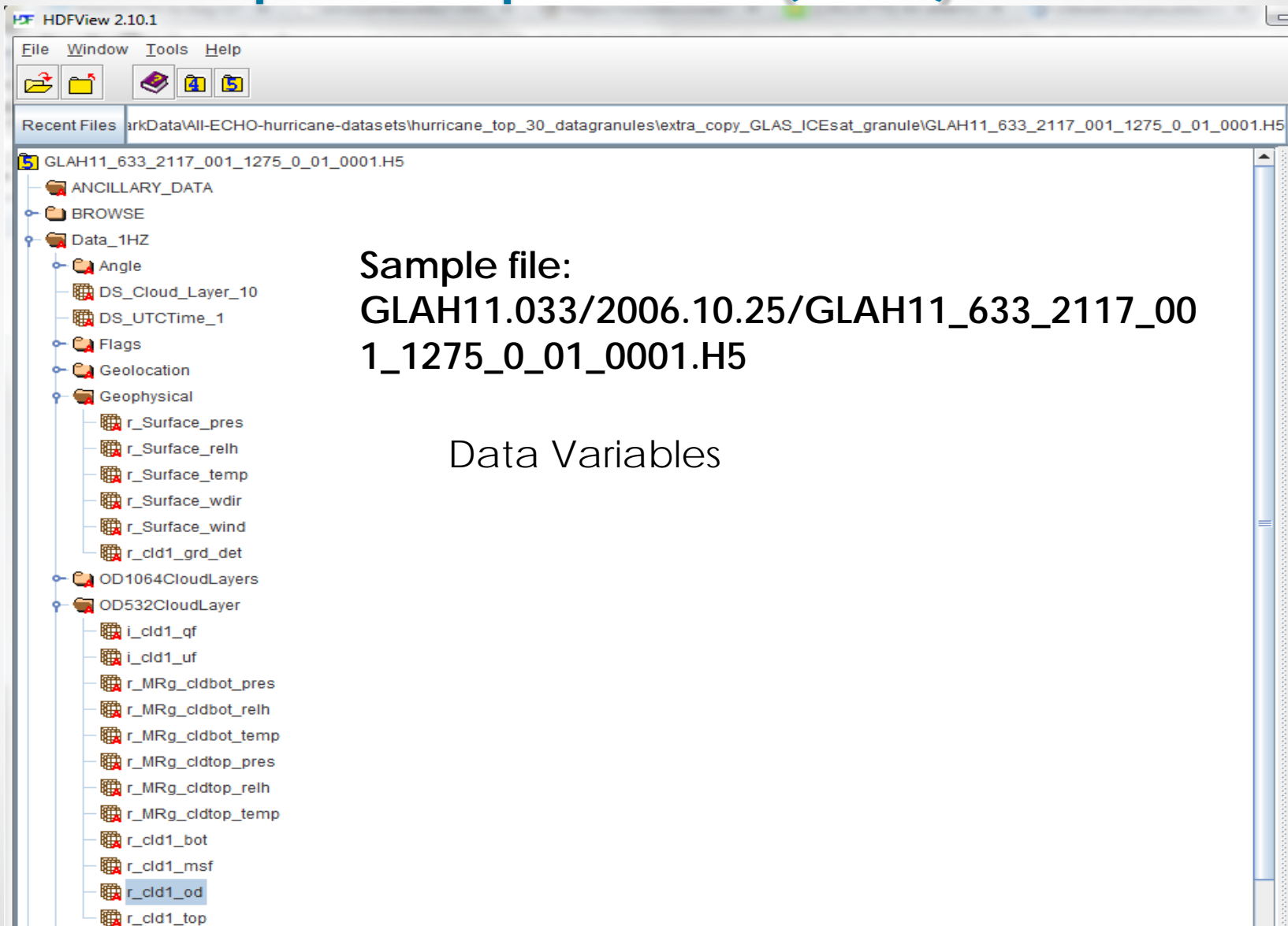
Approach



Example: GLAS/ICESat L2 Global Thin Cloud/Aerosol Optical Depths Data (HDF5) V033 – Dataset Metadata



Example: GLAS/ICESat L2 Global Thin Cloud/Aerosol Optical Depths Data (HDF5) V033



Example: GLASICESat L2 Global Thin Cloud Aerosol Optical Depths Data (HDF5) V033

Science keyword to variable mapping

- r_Surface_relh | Surface Relative Humidity
 - No match
- r_Surface_temp | Surface Temperature
 - No match
- r_Surface_wind | Surface Wind Speed
 - No match
- r_cld1_od | Cloud Optical Depth at 532 nm
 - Score=3 keyword: ATMOSPHERE->CLOUDS->CLOUD OPTICAL DEPTH/THICKNESS
 - Score=2 keyword: ATMOSPHERE->AEROSOLS->AEROSOL OPTICAL DEPTH/THICKNESS

Variable to keyword mapping

- ATMOSPHERE->CLOUDS->CLOUD OPTICAL DEPTH/THICKNESS
 - Score=3 name: r_cld_ir_OD | Cloud Optical Depth at 1064 nm
 - score=3 name: i_cld1_qf | Cloud optical depth flag for 532 nm
 - Score=3 name: i_cld1_uf | Cloud optical depth flag for 532 nm
 - Score=3 name: r_cld1_od | Cloud Optical Depth at 532 nm

- *Found incorrect/incomplete keyword annotation*
- *Can be used **assess metadata quality and suggest keyword annotation!!***

Parameter Mapping Tool

54.172.157.10:5000

News personal Mendeley GKeep NASA Demo HSS GHRC DarkData nspires RResp Unisys Weather - G

Data Parameter Mapping Tool

Datasets

AIRS/Aqua Level 2 Support retrieval (AIRS+AMSU) V005
GHR SST Level 2P USA NASA MODIS Aqua SST:1
MODIS/Terra Temperature and Water Vapor Profiles 5-Min L2 Swath 5km V005
LIS/OTD 2.5 DEGREE LOW RESOLUTION DIURNAL CLIMATOLOGY (LRDC) V2.3.2013
MODIS/Terra Aerosol 5-Min L2 Swath 10km V005 NRT

MODIS/Terra Aerosol 5-Min L2 Swath 10km V005 NRT

Science Keyword Map EDIT

ATMOSPHERE > AEROSOLS > PARTICULATE_MATTER 1
Deep_Blue_Aerosol_Optical_Depth_Land_STD : 1
Deep_Blue_Aerosol_Optical_Depth_550_Land : 1
Aerosol_Type_Land : 1
Aerosol_Cldmask_Byproducts_Ocean : 1
Deep_Blue_Aerosol_Optical_Depth_Land : 1
Aerosol_Cldmask_Byproducts_Land : 1
Deep_Blue_Aerosol_Optical_Depth_550_Land_STD : 1
Optical_Depth_Small_Average_Ocean : 0

Parameter Map EDIT

Optical_Depth_Small_Average_Ocean 1
ATMOSPHERE->AEROSOLS->AEROSOL_PARTICLE_PROPERTIES : 2
ATMOSPHERE->AEROSOLS->CLOUD_CONDENSATION_NUCLEI : 2
ATMOSPHERE->AEROSOLS->AEROSOL_EXTINCTION : 2
ATMOSPHERE->AEROSOLS->AEROSOLS_OPTICAL_DEPTH/THICKNESS : 2
ATMOSPHERE->AEROSOLS->AEROSOL_RADIANCE : 2
ATMOSPHERE->AEROSOLS->CARBONACEOUS_AEROSOLS : 2
ATMOSPHERE->AEROSOLS->DUST/ASH/SMOKE : 2
ATMOSPHERE->AEROSOLS->NITRATE_PARTICLES : 2
ATMOSPHERE->AEROSOLS->ORGANIC_PARTICLES : 2
ATMOSPHERE->AEROSOLS->PARTICULATE_MATTER : 2
ATMOSPHERE->AEROSOLS->SULFATE_PARTICLES : 2
ATMOSPHERE->ATMOSPHERIC_RADIATION->RADIATIVE_FLUX : 2
ATMOSPHERE->ATMOSPHERIC_RADIATION->REFLECTANCE : 2
✓ ATMOSPHERE->ATMOSPHERIC_RADIATION->OPTICAL_DEPTH/THICKNESS : 2

Science Keyword

Parameter

Mapped Science Keywords

Mapped Parameters

MODIS/Terra Aerosol 5-Min L2 Swath 10km V005 NRT

ATMOSPHERE->AEROSOLS->AEROSOL_PARTICLE_PROPERTIES : 2	
ATMOSPHERE->AEROSOLS->CLOUD_CONDENSATION_NUCLEI : 2	
ATMOSPHERE->AEROSOLS->AEROSOL_EXTINCTION : 2	
ATMOSPHERE->AEROSOLS->AEROSOLS_OPTICAL_DEPTH/THICKNESS : 2	
ATMOSPHERE->AEROSOLS->AEROSOL_RADIANCE : 2	
ATMOSPHERE->AEROSOLS->CARBONACEOUS_AEROSOLS : 2	
ATMOSPHERE->AEROSOLS->DUST/ASH/SMOKE : 2	
ATMOSPHERE->AEROSOLS->NITRATE_PARTICLES : 2	
ATMOSPHERE->AEROSOLS->ORGANIC_PARTICLES : 2	
ATMOSPHERE->AEROSOLS->PARTICULATE_MATTER : 2	
ATMOSPHERE->AEROSOLS->SULFATE_PARTICLES : 2	
ATMOSPHERE->ATMOSPHERIC_RADIATION->RADIATIVE_FLUX : 2	
ATMOSPHERE->ATMOSPHERIC_RADIATION->REFLECTANCE : 2	
✓ ATMOSPHERE->ATMOSPHERIC_RADIATION->OPTICAL_DEPTH/THICKNESS : 2	

Remove

Remove

ATMOSPHERE->AEROSOLS->PARTICULATE_MATTER : 0

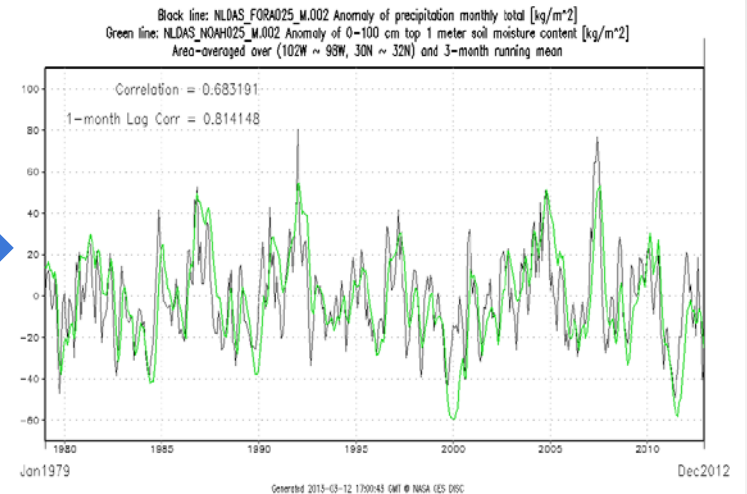
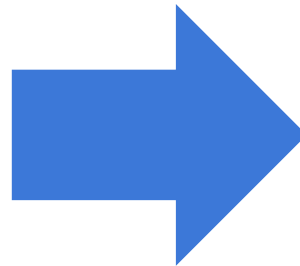
Remove

Edit/Save Mapping

Mapping Scores Generated by Algorithm

Part 3: Rules Engine

What settings should I use to visualize this event?



Data
Variable
?

Dataset
?
Visualization
Type?

Goal: Automate data preprocessing and exploratory analysis and visualization tasks

Strategy

- Service to generate and rank candidate workflow configurations
- Use rules to make **assertions** about **compatibility based on multiple factors**
 - does this data variable make sense for this feature?
 - does this visualization type make sense for this feature?
 - does the temporal / spatial resolution of this dataset make sense for this feature?
- Each compatibility assertion type is assigned weights.
 - ex: Strong = 5, Some = 3, Slight = 1, Indifferent = 0, Negative = -1.
- Based on the aggregated compatibility assertions, we calculate the score for each visualization candidate.

Ruleset Development

Survey asked users to rate characteristics of phenomena features

Feature characteristics for analysis *

What characteristics are of interest when analyzing the feature?

	negative value	indifferent	slight value	some value	strong value
east-west movement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
north-south movement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
temporal evolution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
spatial extent of event	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
year-to-year variability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
may impact seasonal variation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
variation with atmospheric height	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
global phenomena	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
detection of events	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Survey results used to formulate rules

[rule1:

(?feature rdf:type
dd:AshPlume)

->

(?feature
dd:strongCompatibilityFor
dd:temporal_evolution),

(?feature
dd:indifferentCompatibilityFor
dd:east-west-movement),

...

]

Phenomena Feature Characteristic Mappings

Phenomena	East-West Movement	North-South Movement	Temporal Evolution	Spatial Extent of Event	Year-to-Year Variability	May Impact Seasonal Variation	Variation with Atmospheric Height	Global Phenomena	Detection of Events
Volcano - Ash Plume	Indifferent	Indifferent	Strong	Slight	Strong	Strong	Strong	Strong	Strong
Flood	Some	Some	Strong	Some	Some	Strong	Some	Slight	Some
Dust Storm	Strong	Strong	Strong	Strong	Indifferent	Indifferent	Strong	Indifferent	Some

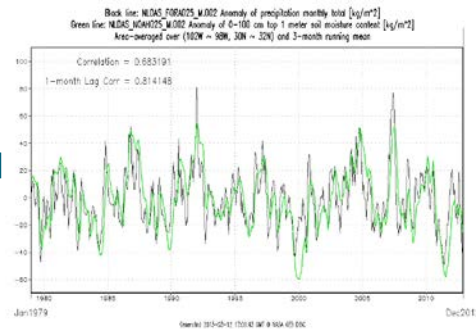
Service to Characteristic Mappings

Service	Visualization	East-West Movement	North-South Movement	Temporal Evolution	Spatial Extent of Event	Year-to-Year Variability	Seasonal Variation	Variation with Atmospheric Height	Global Phenomena	Detection of Events
Time-averaged Map	Color-Slice Map				✓					
Area-averaged Time Series	Time Series			✓						✓
User-defined Climatology	Color-Slice Map						✓			
Vertical Profile	Line Plot							✓		
Seasonal Time Series	Time Series					✓				
Zonal Means	Line Plot								✓	
Hovmoller (Longitude)	Color-Slice Grid	✓								
Hovmoller (Latitude)	Color-Slice Grid		✓							

Compute Compatibility



+



=



Phenomena:
Volcano - Ash
Plume

Service - Area
Averaged Time
Series

**STRONG
COMPATIBILITY
x2**

Temporal Evolution	Detection of Events
Strong	Strong

Area Averaged Time Series : bestFor →	Temporal evolution; Detection of events
---------------------------------------	---

Images from , http://disc.sci.gsfc.nasa.gov/data/releases/images/nldas_monthly_climatology_figure_9.gif, <http://www.clipartbest.com/cliparts/biy/bAX/biybAXGiL.png>

volcanic ash image - By Boaworm (Own work) [CC BY 3.0 (<http://creativecommons.org/licenses/by/3.0>)], via Wikimedia Commons

Integrating Services in Giovanni

- **Tool:** Giovanni is a popular on-line environment that lets users discover, plot, and download a number of geophysical parameters (data variables)
- **Goal:** Leverage Dark Data services and technologies to assist Giovanni users in discovering and exploring data

'Success will be realized when Giovanni requests can be automatically invoked with the appropriate spatial and temporal extents, variables and workflow / visualization type for a particular event'

Giovanni – Standard Edition

EARTHDATA Data Discovery - DAACs - Community - Science Disciplines -

GIOVANNI The Bridge Between Data and Science v 4.17.2 [Release Notes](#) [Browser Compatibility](#) [Known Issues](#)

Select Plot

☒ **Maps: Time Averaged Map** ☐ Comparisons: Select... ☐ Time Series: Select... ☐ Vertical: Select... ☐ Miscellaneous: Select...

Select Date Range (UTC)

YYYY-MM-DD HH:mm to YYYY-MM-DD HH:mm

Valid Range: 1979-01-01 to 2016-02-04

Please specify a start date.

Select Variables

Disciplines

- ☐ Aerosols (122)
- ☐ Atmospheric Chemistry (37)
- ☐ Atmospheric Dynamics (144)
- ☐ Cryosphere (5)
- ☐ Hydrology (369)
- ☐ Ocean Biology (11)
- ☐ Oceanography (8)
- ☐ Water and Energy Cycle (391)

Measurements

- ☐ Aerosol Index (3)
- ☐ Air Pressure (24)
- ☐ Air Temperature (39)
- ☐ Albedo (11)
- ☐ Altitude (4)
- ☐ Angstrom Exponent (16)
- ☐ Atmospheric Moisture (42)
- ☐ Buoyancy (1)
- ☐ CH4 (8)
- ☐ CO (8)
- ☐ CO2 (2)
- ☐ Canopy Water Storage (3)
- ☐ Chlorophyll (2)

Select Region (Bounding Box or Format: West, South, East, North)

-180, -90, 180, 90

Number of matching Variables: 721 of 975 Total Variable(s) included

Keyword:

Variable Name	Source	Resolution	Frequency	Units	Start Date	End Date
<input type="checkbox"/> Aerosol Angstrom Exponent 550/865 nm (Dark Target, Ocean-only) (MOD08_D3 v051)	MODIS-Terra	1°	Daily	1°	2000-03-01	2016-02-04
<input type="checkbox"/> Aerosol Angstrom Exponent 470/660 nm (Dark Target, Land-only) (MOD08_D3 v051)	MODIS-Terra	1°	Daily	1°	2000-03-01	2016-02-04
<input type="checkbox"/> Aerosol Optical Depth 550 nm (Dark Target) (MOD08_D3 v051)	MODIS-Terra	1°	Daily	1°	2000-03-01	2016-02-04
<input type="checkbox"/> Pixel Count of Aerosol Optical Depth 550 nm (Dark Target) (MOD08_D3 v051)	MODIS-Terra	1°	Daily	1°	2000-03-01	2016-02-04
<input type="checkbox"/> Aerosol Optical Depth 550 nm (Deep Blue, Land-only) (MOD08_D3 v051)	MODIS-Terra	1°	Daily	1°	2000-03-01	2007-12-31
<input type="checkbox"/> Aerosol Angstrom Exponent 550/865 nm (Dark Target, Ocean-only) (MYD08_D3 v051)	MODIS-Aqua	1°	Daily	1°	2002-07-04	2015-09-30
<input type="checkbox"/> Aerosol Angstrom Exponent 470/660 nm (Dark Target, Land-only) (MYD08_D3 v051)	MODIS-Aqua	1°	Daily	1°	2002-07-04	2015-09-30
<input type="checkbox"/> Aerosol Optical Depth 550 nm (Dark Target) (MYD08_D3 v051)	MODIS-Aqua	1°	Daily	1°	2002-07-04	2015-09-30
<input type="checkbox"/> Pixel Count of Aerosol Optical Depth 550 nm (Dark Target) (MYD08_D3 v051)	MODIS-Aqua	1°	Daily	1°	2002-07-04	2015-09-30
<input type="checkbox"/> Aerosol Optical Depth 550 nm (Deep Blue, Land-only) (MYD08_D3 v051)	MODIS-Aqua	1°	Daily	1°	2002-07-04	2015-09-30

Vertical Choices

- ☐ **Cross Map, Latitude-Pressure**
Cross Map, Latitude-Pressure
[Details...](#)
- ☐ **Cross Map, Longitude-Pressure**
Cross Map, Longitude-Pressure
[Details...](#)
- ☐ **Cross Map, Time-Pressure**
Cross Map, Time-Pressure
[Details...](#)
- ☐ **Vertical Profile**
Vertical Profile
[Details...](#)

[Help](#) [Reset](#) [Feedback](#) [Plot Data](#)

User needs to decide:

- Variable(s)
- Time
- Space
- Plot type

<http://giovanni.sci.gsfc.nasa.gov/giovanni/>

Giovanni – Dark Data Edition

Rules Service:
highlights
suitable plots
based on
selected event
& variables

Curation
Service: event
type filters
relevant
variables

Selected event & its time Event Client

The screenshot shows the GIOVANNI web interface with the following sections and annotations:

- Select Plot:** Includes dropdowns for Maps, Comparisons, Vertical, Time Series (highlighted with a blue arrow from 'Rules Service'), and Miscellaneous.
- Select Date Range (UTC):** Includes date and time pickers (highlighted with a blue arrow from 'Selected event & its time').
- Select Region:** Includes a text input for 'Volcanoes: Manam Volcano' and buttons for 'Show Map', 'Show Shapes', and 'Show Events' (highlighted with a blue arrow from 'Event Client').
- Select Variables:** Includes a list of variables with checkboxes. The 'Events (all)' section is highlighted with a blue arrow from 'Curation Service'. The 'Event types' list includes 'Volcanoes' (highlighted with a blue arrow from 'Event Client').

At the bottom, there are buttons for 'Help', 'Reset', 'Feedback', 'Plot Data', and 'Go to Results'.

Part 4: Image Retrieval

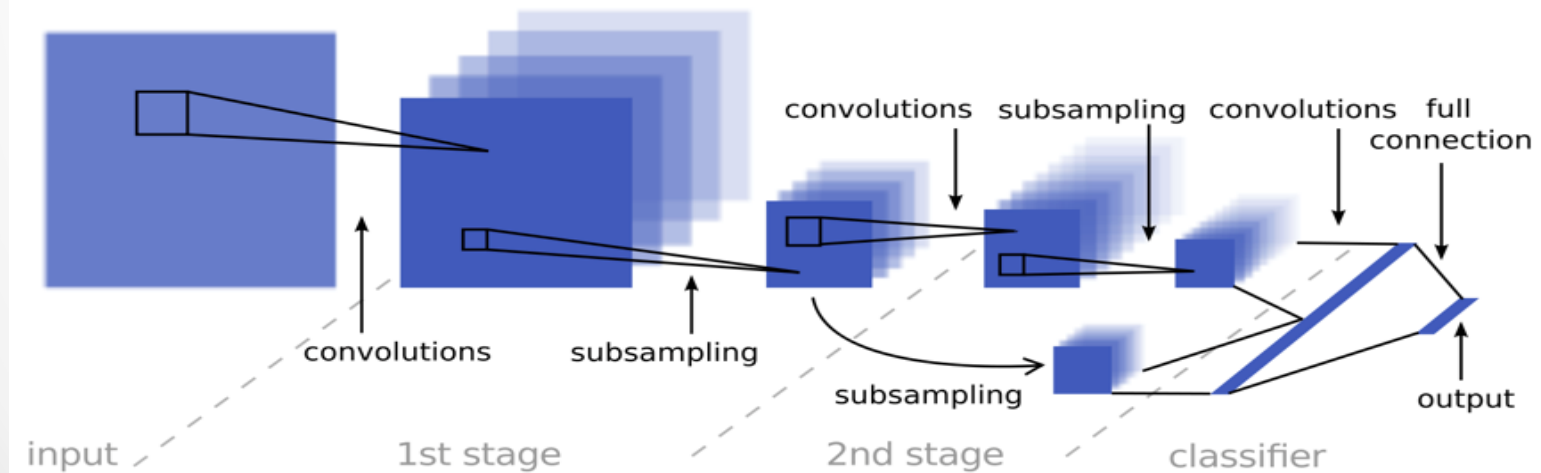
...

Image Retrieval

- Goal: given an image of Earth science phenomenon retrieve similar images
- Challenge: “semantic gap”
 - low-level image pixels and high-level semantic concepts perceived by humans

Deep Learning

- Mimics the human brain that is organized in a deep architecture
 - Processes information through multiple stages of transformation and representation
- Learns complex functions that directly map pixels to the output, without relying on *human-crafted features*



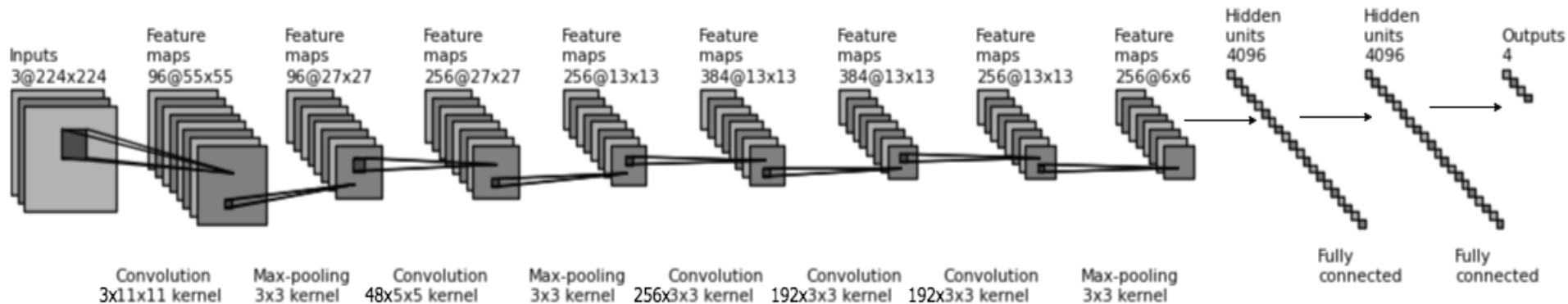
Convolution neural network

Transfer Learning

- CNN requires large number of parameters
- Learning parameters from *a few thousand training samples* is unrealistic
- Transfer learning
 - Use internal representation learned from one classification task to another
 - AlexNet architecture - Krizhevsky et. al.
 - Weights learned from ImageNet 1.3 million high-resolution images
 - State-of-the-art classification accuracy

Experiment: CNN Configuration

Text

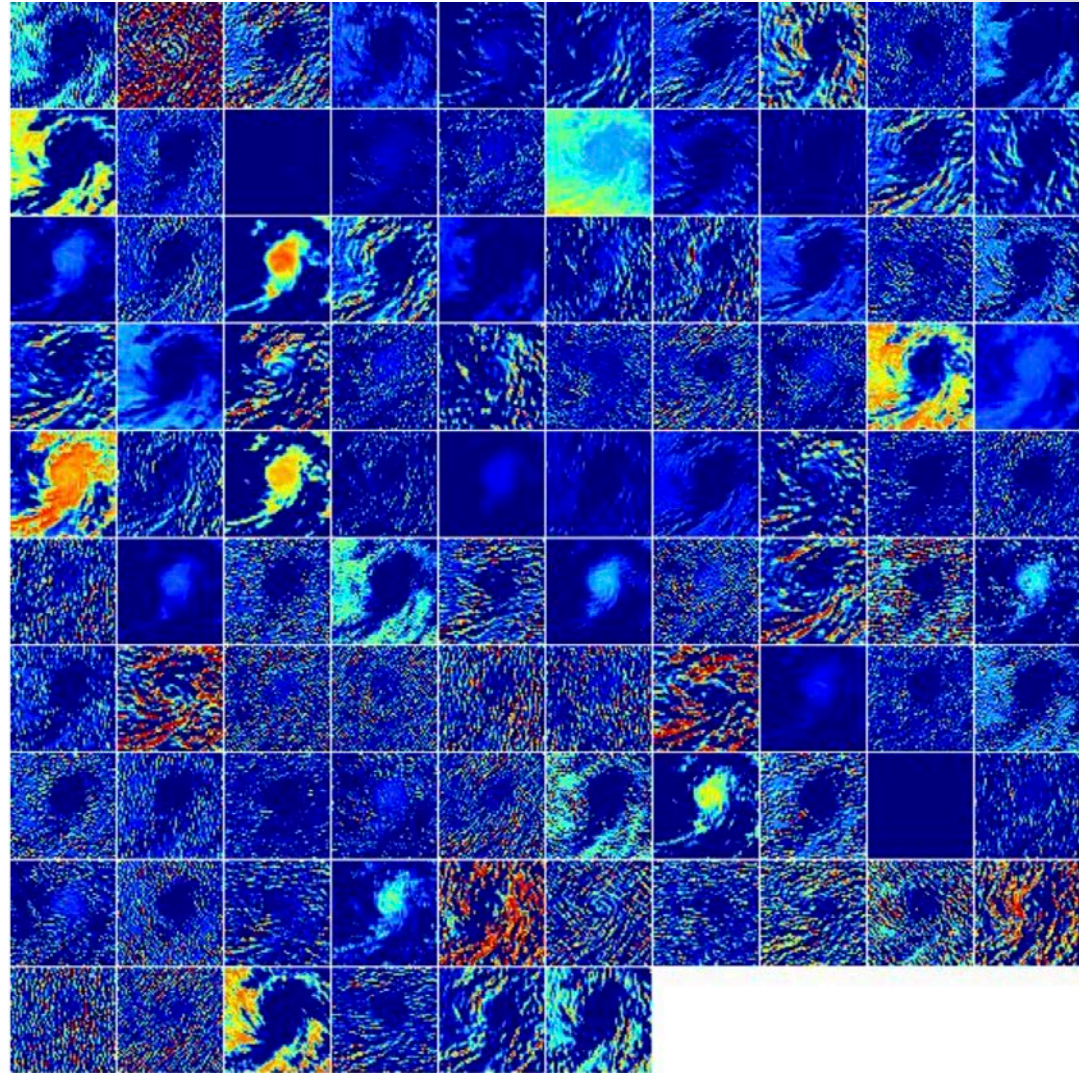


- AlexNet architecture
 - Initialized weights with ImageNet trained model
 - Adaptive learning rate
 - GPU implementation

Experiment CNN – Visualization

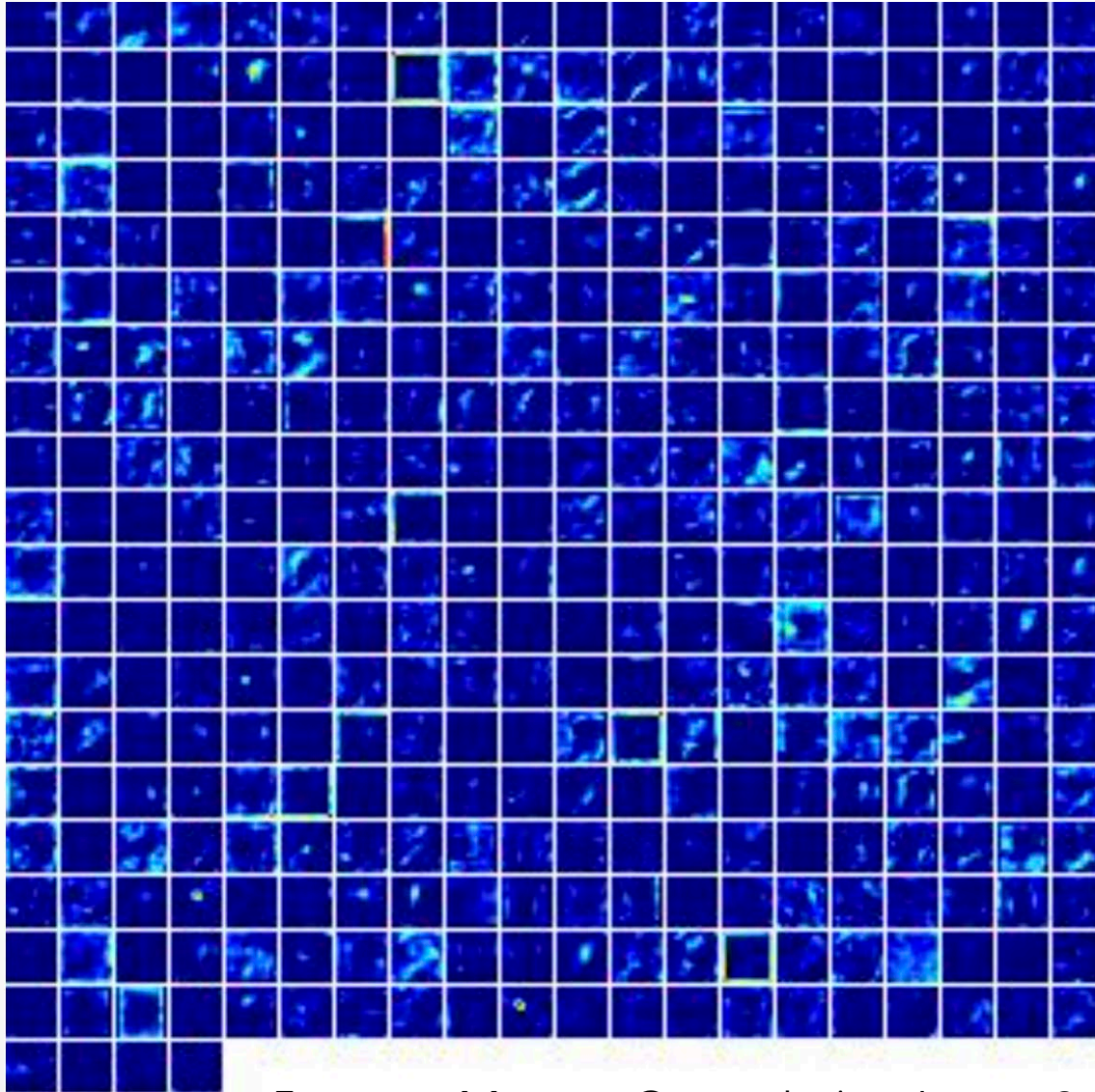


Input Image



Feature Maps – Convolution Layer 1

Experiment CNN – Visualization



Feature Maps – Convolution Layer 3

Results: Confusion Matrix

MODIS Rapid Response Test Images (Images are New to Trained CNN)

True/Pred	Dust	Hurricane	Smoke	Other
Dust	287	8	32	33
Hurricane	0	379	1	10
Smoke	12	12	443	9
Other	33	9	23	211

Overall Accuracy = **87.88%**

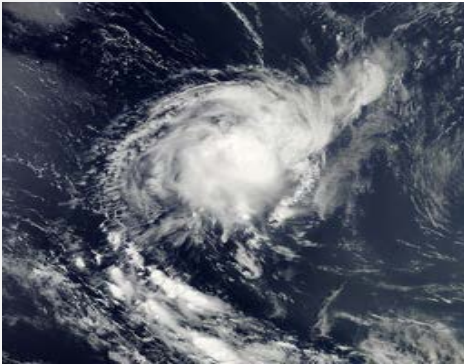
Producer's Accuracy

Dust 86.45%
Hurricane 92.89%
Smoke 88.78%
Other 80.23%

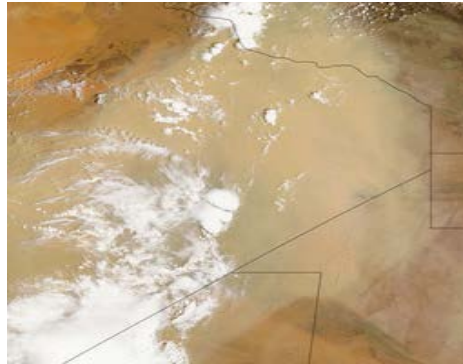
User's Accuracy

Dust 79.72%
Hurricane 97.18%
Smoke 93.07%
Other 76.45%

Results (MODIS Rapid Response)



Hurricane – True Positive



Dust – True Positive



Smoke– True Positive



Hurricane – False Negative



Dust – False Positive



Smoke– False
Positive

Summary

- Building three specific semantic middleware components
 - *Image retrieval service*
 - *Data curation service*
 - *Semantic rules engine*

Infuse the entire middleware or the components into existing NASA data and information system

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